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## Low Emission Vehicles: Consumer Demand and Fiscal Policy

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## Summary

Growing concerns over environmental problems and energy security have redirected the attention of policymakers, manufacturers and consumers to plug-in electric vehicles (PEVs). Global demand for PEVs has been increasing, but the pace of their market penetration is in most countries slow when compared with the pace of penetration of other alternative fuel cars. Perhaps more importantly, however, early demand for PEVs has thus far been strongly dependent on generous fiscal incentives. Even though this is a common feature of many technologies at their early stage of adoption, it is important to analyse the factors hampering a greater market penetration of PEVs and evaluate the impact of the provided fiscal incentives on agent behaviour and economic welfare.

This thesis has a two-fold objective. First, it aims to identify the main barriers to consumer early adoption of PEVs and other low emission vehicles and estimate the impact of these barriers on demand for these technologies. Its second objective is to analyse the effects of recent fiscal policies to stimulate demand for low emission vehicles in the Netherlands on consumer and manufacturer behaviour and economic welfare. To this end, it mainly focuses on policies implemented in the company car market, which has served as the main channel for the penetration of low emission vehicles in the Netherlands and other European countries. Chapters 2 and 3 of this thesis aimed at achieving the first objective, whereas Chapter 5 focused on reaching the second one. Chapter 4 addressed both objectives of the thesis.

Chapter 2 presented a meta-analysis of 33 studies investigating consumer preferences for PEVs and other alternative fuel vehicles to provide insights into the way driving range is traded off for capital costs. Based on 129 WTP estimates, the meta-analysis revealed that consumers are willing to pay, on average, about 67 US\$ (PPP-adjusted 2005 prices) for a 1-mile increase in driving range. Consumer willingness to pay for additional range diminishes as the driving range of the vehicle increases. *Ceteris paribus*, cars with a range of 100 miles (ca. 161 km) have to be priced around 17,000 US\$ less than their petrol-fuelled counterparts to be competitive. The variation in WTP estimates across examined studies can be attributed to differences in the levels of driving range considered, other elements of study design and the country of study. The findings of Chapter 2 confirm that short driving range has been a major limitation to the large-scale

adoption of PEVs and that technological developments permitting longer driving ranges will, to some extent, facilitate their market penetration.

Chapters 3 and 4 have been based on the results of new large-scale surveys among Dutch company and private car drivers. Both surveys used choice experiments to elicit driver preferences for PEVs and internal combustion engine vehicles. Chapter 3 drew on the stated choices of more than 1500 drivers of private cars to examine the influence of environmental concerns on preferences for different types of plug-in electric vehicles (PEVs). Environmental concerns were elicited through Likert-type questions. Latent class and hybrid latent class models were used to study preference heterogeneity and its link to drivers' socio-demographic background and environmental concerns. Chapter 3 showed that environmental concerns are an important predictor of class membership and that highly concerned drivers tend to cluster in classes with stronger preferences for PEVs. Environmental concerns are higher among older and more educated drivers, and lower among drivers with high household income.

More than 15 million cars are provided as fringe benefits by employers in Europe. The company car market is the driving force of changes in European car fleets and one of the main channels for the penetration of PEVs and other low emission vehicles. Chapter 4 developed an approach to estimate the immediate welfare effects of policies using reduced company car tax rates to promote the adoption of PEVs. The approach was built on stated preference data from the survey of company car drivers and a panel latent class model. Even though reductions in company car tax rates are effective in stimulating early demand for PEVs, our estimates revealed that they also lead to important welfare losses, which even outweigh the foregone tax revenues. The result holds even if it is assumed that there are substantial future benefits from the adoption of electric company cars, e.g. in terms of positive network externalities, technological innovation and concomitant environmental benefits. Depending on the assumption made for the magnitude of external benefits provided by PEVs, the annual welfare losses are estimated to be between 42 and 95 million Euros. Welfare losses are mainly caused by tax advantages for plug-in hybrids, whose resemblance to conventional cars justifies much less generosity than the one implied by the provided tax incentives.

Chapter 5 focused on a wider range of low emission vehicles and analysed the impact of tax policies using notched schedules of type-approval CO<sub>2</sub> emissions on the behaviour of car manufacturers and consumers. Using data on new car registrations for the period 2010-2014 in the Netherlands, we demonstrated that notches not only cause salient

changes in consumer demand, but also induce strong responses from car manufacturers. Consumer response to notches is manifested in the notable bunching of car registrations on the tax favourable side of the notch. Bunching is much more dramatic for diesel cars than for petrol ones.

Automakers' response was analysed through a quasi-experimental econometric approach. We showed that manufacturers strongly respond to reductions in cut-off points for diesel cars by reducing the type-approval emission levels of specific models just below the new cut-off points, while even leaving car weight unchanged. The probability that a diesel car is reported to have CO<sub>2</sub> emissions just below the new cut-off point is about 39 percent higher than what would be expected in the absence of a manipulative response. Automakers' response to reductions in cut-off points for petrol cars is much weaker. Provided that the company car share of new diesel cars in the Netherlands is around 70 percent, the findings of Chapter 5 suggest that car manufacturer and consumer reactions are primarily induced by notches in company car taxation.

A number of general conclusions can be drawn from this thesis. First, most full electric vehicles are still far from attractive for the majority of consumers, who seek for PEV alternatives whose attributes resemble the ones of internal combustion engine vehicles. To this end, plug-in hybrid and extended-range electric vehicles have considerable potential to mitigate drivers' current concerns over short driving range and long charging time. Second, early adopters of PEVs are likely to be relatively young workers with high environmental concerns and relatively low driving needs. High income households do not appear more likely to be early PEV adopters neither among company car drivers nor among private car ones. Third, the role of fiscal incentives has been critical for the early adoption of PEVs and other low emission vehicles in the Netherlands. Especially incentives provided in the company car market have been particularly effective in stimulating demand for these technologies. However, the generosity of these incentives, their dependence on car purchase prices, and the use of notched schedules for registration and company car taxes, have led to significant distortions in the car market, the foregoing of substantial amounts of tax revenue and important deadweight losses.